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The Effect of Bubble Aeration and Various Filtration Media on the Iron (Fe) Content of Dug Well Water

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ABSTRACT:

Background: Groundwater usually contains quite large amounts of iron (Fe). The Fe content in water causes health problems and can also cause a metallic taste or smell in drinking water and a yellow color on the walls of the tub and clothes. Iron content: high levels of water consumed will affect the health of the human body, namely damage to the liver, kidneys, and nerves. The presence of iron in water must comply with the quality standard values set by the government, namely 0.3 mg/l for drinking water and 1 mg/l for clean water. By combining various filtering media, such as zeolite and ferrolite, with oxidation reactions using aeration techniques, it is possible to reduce the amount of iron in water. This research aims to determine the effect of bubble aeration and various filtration media on the levels of Fe in excavations.
Materials and Methods: The first treatment is for control, then the second treatment is carried out, namely using variations of bubble aeration and then combined with filtration media such as zeolite, ferrolite, and a combination of both. Data analysis was carried out using the one-way ANOVA statistical test.
Results: The study's findings showed that Fe levels dropped by 16.61% when there was no aeration or when there was aeration at 5, 10, 15, 20, and 30 L/min. They dropped by 31.63% and 45.05% when there was aeration at those rates. %, 51.99%. 55.40% and 67.69%. Variations in bubble aeration discharge can significantly influence Fe levels in dug well water, with a significant value of 0.000.
Conclusion: The use of aeration techniques to reduce Fe levels in dug well water can be done, but it should be combined with other water treatment techniques such as sedimentation and filtration.

Keywords: Aeration, Bubble Aerator, Filtration Media, Iron.

1. Introduction

Water is a very important need for human life. Therefore, if the need for water is not met, it can have a big impact on health and social insecurity. The Regional Drinking Water Company (PDAM) of the relevant city is responsible for managing the supply of hygienic water in Indonesia, particularly on a large scale. For areas that do not yet receive clean water services from PDAM, they generally use groundwater using dug wells or drilled wells, river water, rainwater, spring water, and others[1]. Because water is a vital need, disease transmission or water poisoning may also occur. It contains substances that can cause poisoning[2]. In the human body, around 50–80% consists of fluid. The main and vital use of water for life is as drinking water.

Groundwater can come into contact with various kinds of materials found in the earth, including iron and manganese[3]. It has been proven that in many countries there is a prevalence of water and sanitation-related diseases that cause many people to fall ill and even die[4]. The depth of the water in the soil is one of many factors that affects the iron content in water. The deeper the water penetrates, the higher the solubility of iron, the lower the pH of the water, and the greater the presence of dissolved gases in the water (CO2 and H2S). Fe metal is a type of essential heavy metal that living things require in specific amounts. However, Fe levels that exceed quality standards can harm the environment and public health[5]. Water that contains iron will cause a fishy, metallic taste in the water, a brown color on white clothes, brown stains appearing on the walls of the tub, and blockages in the pipes. High levels of iron in the water consumed will affect the health of the human body, namely damage to the liver, kidneys, and nerves, and cause hemochromatosis [3]. The maximum allowable iron content in drinking water is 0.3 mg/l[6].

Filtration can reduce excess iron. Filtration is the process of separating solid substances from fluids (liquid or gas) by carrying them using a porous medium or other porous material to remove as much fine suspended solids and colloids as possible. Apart from being able to reduce the solid substance content, filtration can also reduce the bacterial content and remove color, taste, odor, iron, and manganese[7]. It depends on the medium that the fluid being filtered passes through. Filtration media generally have variations in size, shape, and chemical composition. The quality of filtration media is based on its size, surface charge, solid geometry, and capture capacity on the surface.

Therefore, using granular filtration media can remove particles from water[8]. The most commonly known granular media in water treatment are sand and anthracite. Examples of filtration media that are effective and often used in clean water treatment in the community are silica sand, activated charcoal, zeolite, ferolite, manganese greensand, and cation resin. Each filtration media has different characteristics and benefits: silica sand is generally used as a pre-filter to be processed with the next filter; activated carbon can remove odors and tastes; absorb particles; and remove organic compounds in water; zeolite sand can increase oxygen levels, provide freshness in water, and absorb light limestone in water; ferolite, which functions to remove high levels of iron content; manganese, odor, and yellow color in water; and manganese greensand can remove manganese content and oily top layers in water; and resin media, which is known as a softener for water with a high level of hardness[9]. Researchers have already found that using zeolite, ferrolite, manganese filter media, or a mix of these media did not lower Fe levels; instead, they raised Fe levels by 11.05%, 5.99%, 21.78%, and 40.98%, respectively[10]. Therefore, an effective Fe processing method must be sought.

A clean water treatment method that is popular and effective and can be applied to households is water treatment using aeration techniques. The aeration technique can be carried out using several types of methods with different levels of effectiveness, one of which is by using a bubble aerator, because the use of the bubble aerator aeration method is technically quite simple, not too expensive, and easy to implement, namely by inserting air through an aerator machine. in water in an aeration tank, which can be freely purchased at ornamental fish equipment shops and is practical to use[11]. Dug wells are a means of clean water for every community in rural and urban areas. A dug well is a source of clean water that comes from shallow soil layers. Apart from the soil layer, metal content and contaminants that pollute dug well water can come from seepage of waste and human waste. A dug well that is a source of clean water must have good construction and location requirements. This is very necessary so that the water quality of dug wells meets the requirements or is safe under the regulations that have been set[12]. If the dug-well water is settled or left for a while, a yellow precipitate will form. The large amount of iron content in the water means that people cannot use the water to meet their daily needs, such as drinking water, bathing, or washing.

2. Materials and Methods

In order to deliberately create an event or circumstance that will be the subject of further study, researchers conduct experimental research. The research design used was a completely randomized design (CRD) with a pretest-posttest control group design[13]. The subject of this research is artificial water samples with a Fe concentration of 8.79 mg/L. Concerns about fluctuations in Fe concentrations in dug well water during the research period due to changes in weather factors led to the use of artificial water samples in this study. The number of research samples is part of the number of artificial water samples. After carrying out the experimental process, 24 samples were taken. Sample replication was carried out four times because the aim was to obtain relevant data so that the data obtained was representative. The research was carried out in steps, with the first step being to assemble the research reactor as shown in Figure 1, then making an artificial sample solution. The sample water used was collected in a 200-liter container, after which the Fe content was measured before the treatment continued. Determine the aeration time based on the research that has been carried out, namely for a long time of 40 minutes[14]. After all parts of the installation are filled with samples, the first control is carried out, and the experimental process is carried out without aeration. After that, the second, third, fourth, fifth, and sixth treatments use a bubble aerator with an airflow of 5, 10, 15, 20, and 30 L/min. Each treatment was repeated four times[15]. After that, 1.00 ml of each water sample was collected for Fe examination after treatment.

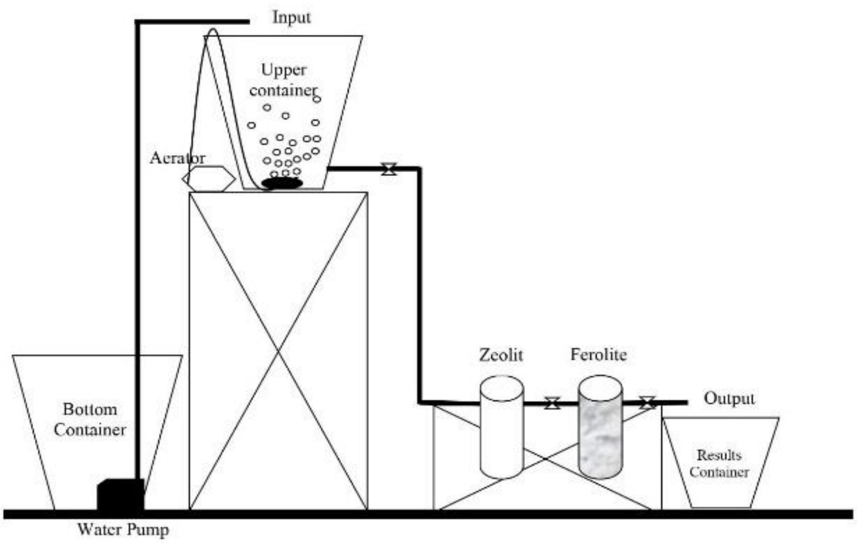


Figure 1. Research Reactor

3. Results

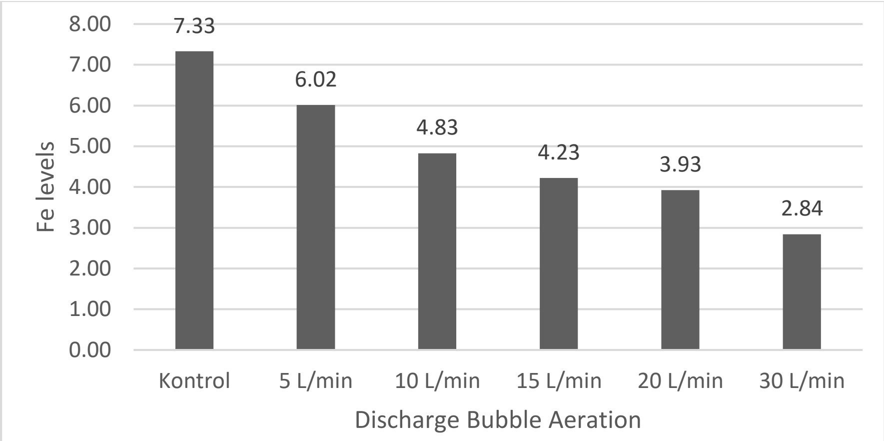
The influence of bubble aeration and various filtration media on the iron (Fe) content of dug well water can be seen in the following table:

Table 2. Research Results on the Effect of Bubble Aeration and Various Filtration Media on Iron (Fe) Content of Dug Well Water in 2023

Repetition	Discharge Bubble Aeration					
	Control	5 L/min	10 L/min	15 L/min	20 L/min	30 L/min
I	7.21	5.72	5.42	4.72	4.87	3.42
II	7.55	6.31	5,10	4.49	4.11	3.75
III	7.07	5.45	4.12	3.57	2.96	2.04
IV	7.49	6.58	4.68	4.12	3.76	2.16
Average	7.33	6.01	4.83	4.22	3.92	2.84

Source: primary data (processed 2023)

Based on table 2 above shows that the average Fe for the control group without bubble aeration is 7.33 mg/ L, for aeration flow of 5 L/min is 6.01 mg/L, aeration flow of 10 L/min is 4.83 mg/L, the aeration flow of 15 L/min is 4.22 mg/L, the aeration flow of 20 L/min is 3.92 mg/L and for the aeration flow of 30 L/min it is 2.84 mg/L. Changes in iron (Fe) parameters with various bubble aeration discharges can be seen in the following graph:



Picture. 1 Graph of Average Fe Content (mg/L) with various bubble aeration discharges

Based on the graph above, it can be seen that the lowest Fe content occurs at a bubble aeration discharge of 30 L/min, which is as large as 2.84 mg/L. The percentage difference in Fe content after the aeration process with various bubble aeration discharges can be seen in Table 3 below:

Table 3 . Percentage Difference in Fe Content (mg/l) After Carrying Out the Aeration Process with Various Bubble Aeration Discharges

Discharge Bubble Aeration	**Initial Fe Content (mg/L)**	**Average Final Fe Content (mg/L)**	**Percentage Difference**
Control	8.79	7.33	16.61
5 L/min	8.79	6.01	31.63
10 L/min	8.79	4.83	45.05
15 L/min	8.79	4.22	51.99
20 L/min	8.79	3.92	55.40
30 L/min	8.79	2.84	67.69

Source: primary data (processed 2023)

Based on Table 3, it is known that at control or without aeration there was a decrease of 16.61%, while at aeration discharge of 5, 10, 15, 20, and 30 L/min there was a decrease in Fe levels of 31.63%, 45, respectively. 05%, 51.99%. 55.40% and 67.69%.

To find out whether the population variations are the same or not, a homogeneity test is carried out using Levene's test, as shown in the following table:

Table 4. Homogeneity of Variance Test

ariable	g,	ef.
on (Fe) Content	103	omogeneous Data

From Table 4 above, it can be seen that the Fe content data is the same or homogeneous because the significance value is greater than 0.05. To see the effect of bubble aeration and various filtration media on the iron (Fe) content of dug well water, see the following one-way ANOVA analysis table:

Table 5. Anova test results on the effect of bubble aeration and various filtration media on the iron (Fe) content of dug well water in 2023

No	**Variable**	**Average**	**Std Deviation**	**95%CI**	***p*-value**

1	Control	7.33	0.23	6.97 - 7.69	0,000
2	5 L/min	6.02	0.52	5.19 - 6.84	
3	10 L/min	4.83	0.56	3.94 - 5.72	
4	15 L/min	4.23	0.50	3.43 - 5.02	
5	20 L/min	3.93	0.79	2.66 - 5.19	
6	30 L/min	2.84	0.87	1.46 - 4.23	

From Table 5 Above, it can be seen that there is a significant difference (p = 0.000) between each treatment bubble aeration discharge on the iron (Fe) content of dug well water. The test continues with the test Least Significant Difference (L SD) as in Table 6 below:

Table 6. Advanced Test Results LSD *Test* The Effect of Bubble Aeration and Various Filtration Media on the Iron (Fe) Content of Dug Well Water in 2023

Aeration Discharge	Aeration Discharge	Average Difference	S.E	*P Value*	95%CI
Control	5 L/min	1.31 *	0.44	0.01	0.40 - 2.23
	10 L/min	2.50 *	0.44	0.00	1.59 - 3.41
	15 L/min	3.10 *	0.44	0.00	2.19 - 4.02
	20 L/min	3.40 *	0.44	0.00	2.49 - 4.32
	30 L/min	4.49 *	0.44	0.00	3.57 - 5.40
5 L/min	Control	-1.31 *	0.44	0.01	-2.23 - -0.40
	10 L/min	1.18 *	0.44	0.01	0.27 - 2.10
	15 L/min	1.79 *	0.44	0.00	0.88 - 2.70
	20 L/min	2.09 *	0.44	0.00	1.18 - 3.00
	30 L/min	3.17 *	0.44	0.00	2.26 - 4.09
10 L/min	Control	-2.50 *	0.44	0.00	-3.41 - -1.59
	5 L/min	-1.18 *	0.44	0.01	-2.10 - -0.27
	15 L/min	0.60	0.44	0.18	-0.31 - 1.52
	20 L/min	0.90	0.44	0.05	-0.01 - 1.82
	30 L/min	1.99 *	0.44	0.00	1.07 - 2.90
15 L/min	Control	-3.10 *	0.44	0.00	-4.02 - -2.19
	5 L/min	-1.79 *	0.44	0.00	-2.70 - -0.88
	10 L/min	-0.60	0.44	0.18	-1.52 - 0.31
	20 L/min	0.30	0.44	0.50	-0.61 - 1.21
	30 L/min	1.38 *	0.44	0.01	0.47 - 2.30
20 L/min	Control	-3.40 *	0.44	0.00	-4.32 - -2.49
	5 L/min	-2.09 *	0.44	0.00	-3.00 - -1.18
	10 L/min	-0.90	0.44	0.05	-1.82 - 0.01
	15 L/min	-0.30	0.44	0.50	-1.21 - 0.61
	30 L/min	1.08 *	0.44	0.02	0.17 - 2.00
30 L/min	Control	-4.49 *	0.44	0.00	-5.40 - -3.57
	5 L/min	-3.17 *	0.44	0.00	-4.09 - -2.26
	10 L/min	-1.99 *	0.44	0.00	-2.90 - -1.07
	15 L/min	-1.38 *	0.44	0.01	-2.30 - -0.47
	20 L/min	-1.08 *	0.44	0.02	-2.00 - -0.17

* there is a significant difference (<0.05)

Based on Table 6 above it can be seen that there is a significant difference between each aeration discharge treatment group and the other treatment groups ($p<0.05$), except for the 10 L/min aeration discharge group with the 15 L/min aeration group and the 15 L/min groups with 20 L /min ($p>0.05$).

4. Discussion

The element iron is found in almost all groundwater. Groundwater generally has a relatively low concentration of dissolved oxygen, causing anaerobic conditions. This condition causes the concentration of iron and manganese in the insoluble mineral form $Fe3+$ to be reduced to soluble iron in the form of $Fe2+$ ions. The iron concentration in groundwater varies greatly from 0.01 mg/l to ±25 mg/l [16]. Iron removal processes include ion exchange, oxidation, coagulation, filter media, and biological processes. However, the chemical oxidation process is most often used in water supply systems. This involves adding an oxidizer to raise the level of oxidation to turn dissolved iron and manganese into precipitate, which can then be processed further through sedimentation and/or filtration[1].

]. In the research results, the use of various variations in bubble aeration discharge can significantly reduce Fe levels in sample water. However, it is felt that it is still necessary to continue using filtration media for more optimal results. The use of filter media is one method of eliminating dissolved iron in water, which is often carried out after the aeration process. Abdur Rahman's research in Jakarta concluded that the optimum conditions for removing Fe were 30 minutes for contact time and 2 mL/minute for filtration rate. Under these conditions, zeolite reduces Fe by 55% in groundwater containing 3.6 mg/L Fe [17]. Effective Fe reduction can be done with integrated processing between aeration and slow sand filter media, so that it can reduce Fe levels in water by up to 85% [18]. Aeration, which is the process of bringing water and air into contact with each other naturally or artificially to raise the amount of dissolved oxygen in water, is a very good way to lower Fe levels right now, since it can lower Fe levels to 100% and raise the redox potential by up to 2 mV [19].

Another effort to increase the removal of dissolved iron from groundwater is by using a diffuser aerator, increasing the air discharge and length of aeration time to meet the established quality standards[20]. In general, iron in water can be dissolved as Fe^{2+} (ferrous) or Fe^{3+} (ferric), suspended as colloidal grains (< 1 μm in diameter) or larger, such as Fe_2O_3, FeO, FeOOH, $Fe(OH)_3$, and so on, and combined with organic substances or inorganic solid substances such as clay. Ferrous ions can be oxidized to become ferric ions, which do not dissolve homogeneously in water, by contacting the water with air to increase the dissolved oxygen content. The aeration process allows the oxidation process of Fe element compounds in ferrous form ($Fe2+$) to become ferric form ($Fe3+$). Divalent ferrous compounds tend to be easily soluble in water, so these compounds must be converted into the 3-valent ferrous form so that they can be filtered in the filtration media. Iron hydroxide with a valence of 2 $Fe(HCO3)2$, which still has high solubility in water, undergoes an oxidation process through an aeration unit so that a reaction (ions) will occur to become $Fe(OH)3$. Stoichiometrically, it takes 0.143 mg/l oxygen to oxidize 1 mg/l iron. According to the oxidation reaction, every 1 mg/l of $Fe2+$ will produce 1.913 mg/l of iron deposits [21].

The presence of iron in water can be caused by the low solubility of oxygen gas in the water phase and the low efficiency of oxygen transfer from the aeration technology currently used[22]. Aeration is a mass transfer process in which gas is dispersed into a liquid by utilizing air inflation or agitation[23]. The initial water depth was also crucial, where greater depth could drive the potential for bubble shrinkage so that they were more liable to contract[24]. The use of filtration media is a further treatment that can be carried out to significantly reduce Fe in water after aeration treatment. Using aeration techniques and partial filtration media will produce ineffective processing results because Fe is a compound that cannot easily be separated chemically or physically. without going through a combined process.

5. Conclusion

Based on statistical tests, there is an influence of various variations in bubble aeration discharge on Fe levels in dug well water. Bubble aeration can reduce Fe levels by up to 67.69% at a discharge variation of 30 L/min. The use of aeration techniques to reduce Fe levels in dug well water can be done, but it should be combined with other water treatment techniques such as sedimentation and filtration.

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